Midpoint Project Status Report
SMECO/Navy PEM Fuel Cell Demonstration
Contract #DACA42-02-C-0003

Site No. 1 and Site No. 2
Patuxent River Naval Air Station
Patuxent River, Maryland

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Southern Maryland Electric Cooperative, Inc.
Michael Rubala, Energy Services Supervisor
15065 Burnt Store Road
Hughesville, MD 20637

Points of Contact:

SMECO:
Mike Rubala, Energy Services Supervisor
Phone: 301-274-4338
E-mail: rubalam@smeco.com

Patuxent River NAS:
Mike Oliver, Utilities Engineer
Phone: 301-757-4723
E-mail: olivermg@navair.navy.mil

Energy Co-Opportunity
Brian Wierenga, Technical Support and Sales Representative
Phone: 231-861-7367
E-mail: wierenga@oceana.net

H-Power Corporation
Anita La Mendola, Technical Support
Phone: 514-956-2375
E-mail: alamendola@hpower.ca

Installation Overview

During the months of August, September, and early October 2002, site preparations were conducted and completed for two Proton Exchange Membrane fuel cell (PEMFC) units located on the Patuxent River Naval Air Station (PRNAS), Patuxent River, Maryland. Plumbing, wiring, trenching, fuel connections, co-generation connections, and pad installations were addressed per each site's individual requirement. On October 17, 2002, two H-power fuel cells (one natural gas and one propane) arrived at Southern Maryland Electric Cooperative's (SMECO) Hughesville headquarters. They were subsequently loaded on a SMECO flatbed truck for delivery to the Patuxent River Naval Air Station. Each of the installations is discussed in further detail below. Site No. 1 is the installation of a natural gas PEMFC and site No. 2 is that of a propane-fueled PEMFC.

Prior to both PEMFC's final installation SMECO had to receive final approval for several critical applications. One, was required approval from Public Works Department (PWD) concerning water taps for feed water to the fuel cell. Second, design an effective pre-heat tank-plumbing scheme to utilize cogenerated heat for domestic hot water use. Third, work with the base HVAC contractor to design a wiring control process for the adaptation of a hot water coil for space heating, again using cogenerated heat. Each of these efforts will be addressed individually for both site No. 1 and No. 2 below.

Site No. 1 Preparation

Site No. 1 is the installation of the natural gas PEMFC unit at a private residence. Navy officials requested the fuel cell be placed about sixty feet from the house. Wiring and plumbing had to run an additional twenty feet of length within the home. Two trenches were provided from the house to the fuel cell. One trench was for the natural gas pipe. The second trench was for power and control wiring, deionized feed water, plus a supply and return water pipe for cogeneration use. A nitrogen cylinder was located in an adjacent building and piped underground to the PEMFC, as well. The nitrogen is used to purge the fuel cell when the unit goes into shut down mode. Below are photos of the trench, pad preparation, building interior wiring and plumbing connections, and PEMFC being off loaded and prepared for operation.

Site No. 1 (Quarters Y) Installation

Trending across the yard

- *One trench was provided for the natural gas pipe leading from the house gas main to the fuel cell pad.*
- *The other trench was for power and control wiring, supply and return co-generated hot water, and the de-ionized feed water.*

Pad with utility stub-ups

- *Pad was installed on pressure-treated 6x6 timbers, all resting on a six-inch-thick gravel bed.*
- *The required nitrogen for purging the fuel cell was piped underground from a canister located in the garage, just to the right of the pad.*

Interior wiring with transfer switch

- *Initially all building loads were relocated to the sub-panel served by the fuel cell transfer switch.*
- *Fuel cell battery charger and fuel cell onboard emergency heater were served exclusively from the grid-supplied panel.*
- *The transfer switch had an emergency shut off button enabling the residents to quickly shut down the unit.*

The sub-panel circuits supported by the fuel cell automatic transfer switch are as follows:

- Interior and exterior lighting
- Refrigerator
- Dishwasher
- Television
- Natural gas boiler and circulator pumps
- Clothes washer
- Clothes dryer (electric)
- Microwave
- Wall receptacles
- Personal computer system

Excluding the boiler, the above appliances represent the baseload appliances year round. When we enter the cooling season, we have not decided as of yet whether we will stay with the same connection scheme or rotate most circuits back to the grid-only panel and attempt to support the central air conditioner. Due to the lifestyle of the occupants, one particular day of the week became a peak usage day. The clothes dryer was used extensively during this period, which taxed the load carrying capabilities of the fuel cell's onboard batteries. When the fuel cell switched back to grid, in response to the overload, the dryer logic control would be disrupted and turn off the dryer. The fuel cell would then see the load reduction and switch back to PEMFC operation. Later in the day the occupants would find out their clothes were not dry and in response turn the dryer back on. Resulting in the whole cycle being repeated. After several frustrating weeks of this, we switched the dryer load back to grid, thus eliminating the problem. The power use profile of this residence turned out to be a stressful one for the PEMFC. For many hours the load would only be about 400 to 600 watts, which was too low for continuous operation for the stack and onboard processes. With loads that low, the PEMFC was consuming more energy to maintain onboard operations than the loads placed on it. Our solution was to provide two 1,200-watt portable electric heaters to heat an unheated enclosed sun porch. The occupants operated the heaters when they were not home or during low appliance use. This provided a steady load on the PEMFC and improved its operational efficiencies. It also provided a more comfortable sun porch, which was very much appreciated by the occupants. During occupied periods, the load ranged between 2.5 kW to 4.0 kW on average. During unoccupied periods (with the electric heaters operating) the load ranged between 1.5 kW to 2.5 kW. When the heating season ends, and before air conditioning starts, we will use the portable heater(s) to dry out the basement.

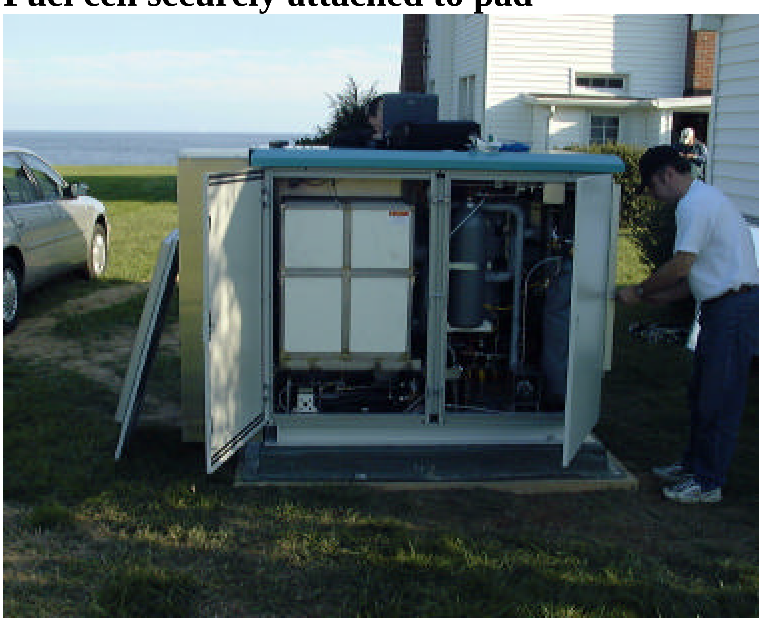
Co-generated hot water tank

- *This vessel served as a preheat tank for the domestic water heater.*
- *The circulating pump operated at a 3.5 gpm flow rate.*
- *This was an open loop design using potable well water at 55 degrees F.*
- *Preheated water entered the main water heater tank at temperatures above 125 degrees F.*

Fuel cell off loaded by boom truck

- *The H-Power RCU-4500 fuel cell weighs about 3,100 pounds, requiring a boom truck to safely lower the unit on the pad.*
- *Once lowered on the pad, all plumbing and wiring connections are made in a relatively short time.*

Fuel cell securely attached to pad



- *H-Power technicians begin the final installation process.*
- *Once all connections are completed by the plumber and electrician, H-Power technicians will secure all fittings that may have come loose during shipping.*

Installation complete at Site No. 1

Note 1: During initial set-up procedures, the fuel cell took much longer to achieve proper operating temperatures due to cold winds blowing off the Chesapeake Bay. H-Power engineers felt a wind fence would resolve the problem. The fence indeed had a positive impact on reducing start-up time. On later occasions, and in much colder weather, fuel cell start up occurred within normal operating time frames.

Note 2: The large nitrogen canister for system purge requirements is located in the small building just to the right of the fuel cell. The nitrogen supply tube runs underground in a plastic conduit from the garage to the fuel cell pad.

Site No. 2 Preparation

Site No. 2 is the installation of a propane-fueled PEMFC at the PRNAS Conservation building. This site was selected for its intrinsic value as the focal point for all base environmental endeavors. The building houses a classroom used by the public for conservation programs and offices for employees. The building also is the home for many live animals on display for educational purposes. This building was an ideal location for a propane supplied fuel cell. During construction we took special precautions in regards to public safety. We fenced off the area from curious onlookers and covered open trenches during non-construction periods. The placement of this fuel cell is much closer to the building compared to site No. 1. A single trench for wiring conduits, co-generated hot water pipes, nitrogen gas, and de-ionized feed water is only fifteen feet in length. All connections inside the building are within five feet from the exterior wall penetration. An additional trench was provided for the propane fuel pipe running about 70 feet to an above ground 500-gallon storage tank. Below are photos of the utility stub-ups, pad preparation, building interior wiring and plumbing connections, and PEMFC installation.

Site No. 2 (Conservation Building) Installation

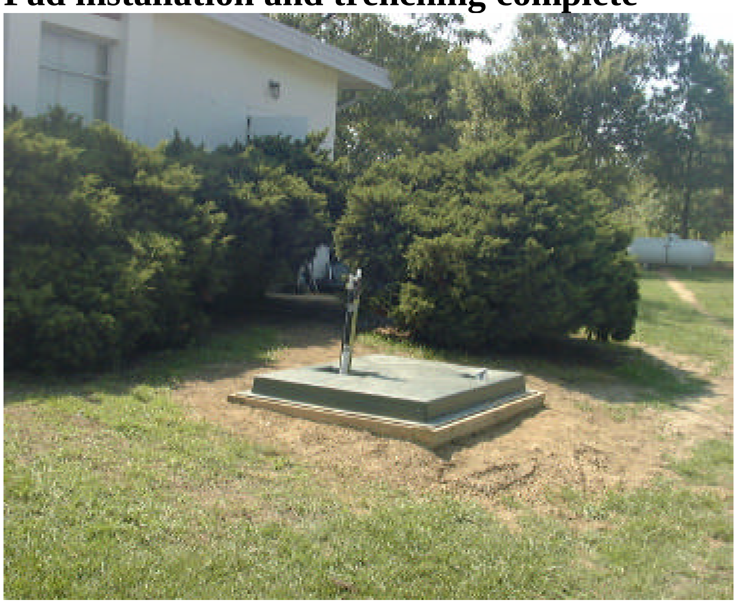
View of the PRNAS Conservation Building

- *The base Environmental Protection and Conservation building was selected for its easy access by the public and load requirements suitable for the 4.0 kW fuel cell.*
- *Site was also suitable for propane storage and a co-generated heating application.*

Trench and stub-ups prior to pad installation

- *Here the stub ups for all connections are easily seen.*
- *This area is open to the general public and had to be fenced off and covered each night for safety.*
- *After backfill, a 6-inch gravel base was added and a 6x6 timber foundation installed.*

Pad installation and trenching complete



- *The 6x6 foundation has been installed and the pad securely attached.*
- *All trenching and backfill work complete.*
- *Notice the trench leading from the 500 gallon propane tank 70 feet from the fuel cell location. Propane for the fuel cell is provided at a 20 psi pressure level.*

Fuel cell transfer switch and sub-panel

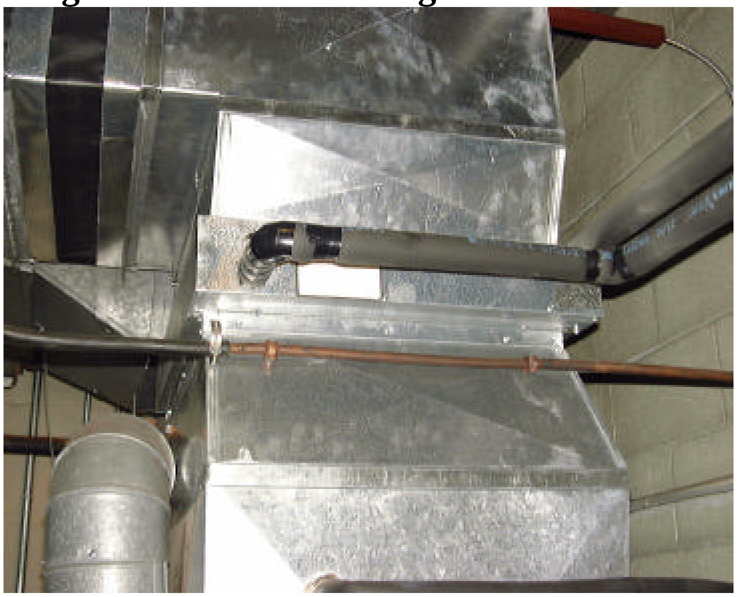
- *The equipment room is located 15 feet from the fuel cell location with easy access for public viewing during planned educational programs.*
- *Being a commercial building, all power and control wiring required proper conduits and support.*

The sub-panel circuits supported by the fuel cell automatic transfer switch are as follows:

- Building interior lighting
- Nine desk-top computers
- Animal display life support systems
- Oil forced air furnace
  - Blower and burner in winter
  - Blower only in summer

The average load is between 3.0 and 3.5 kW, which is an ideal load for the fuel cell stack. Even better is that being a commercially operated building, the energy load is relatively consistent eight to ten hours per day. This consistent 75 to 80 percent stack loading maximizes fuel cell stack efficiency and reduces internal processing stresses according to H-Power. During the summer cooling months, some rotation of circuits are planned. This will prevent fuel cell stack overload due to the anticipated air conditioner loads.

Co-generated heat exchanger attached to furnace



- *A hot water coil was installed into the supply-side plenum of the oil furnace.*
- *Co-generated hot water collected from the fuel cell stack would circulate through this coil via a circulating pump with a 3.8 gpm flow rate.*
- *A two-stage thermostat wiring control was to provide proper heating control between the hot water coil and furnace output.*

The base HVAC contractor installed a two-stage thermostat to provide proper control as to what heat source would heat the building as a function of the structure's heating requirements. Site No. 2 fuel cell installation was engineered to expose the fuel cell to a steady load requiring a 75-to 80-percent stack output during business hours. This loading scheme generates a nominal 22,000 Btu's per hour of available co-generated heat. The circulator pump is powered by the fuel cell (no grid connection) via a line voltage relay off the first stage thermostat. When the first stage is activated, the furnace blower and circulator pump are energized, allowing co-generated hot water into the plenum-inserted heat exchanger. Should the heat output be insufficient, the second stage would engage igniting the oil burner and disengage the circulator pump. We discovered during a very cold weather period that the second-stage mode-wiring scheme did not de-energize the co-generated hot water loop circulator pump as assumed.

We determined that whenever the ambient outdoor temperature was above 45 degrees Fahrenheit, the first stage heat (fuel cell co-generated Btu's) satisfied the building heating requirements exclusively. Generally, below 45 degrees the second stage would engage due to a three-degree drop in building temperature below the first stage setting. The thermostat would cycle between first and second stage until outdoor temperatures rose above 45 degrees again. The average winter temperature at PRNAS is 42 degrees Fahrenheit making this a good location for this type of application. Recorded first-stage heat output (fuel cell co-generated output measured in the supply air stream) averaged around 106 degrees Fahrenheit. The return averaged around 75 degrees Fahrenheit for a delta temperature rise of 31 degrees. That is a respectable heating performance output from the fuel cell. When we witnessed Stage Two operations and the fuel cell was at full load conditions, the hot water heat exchanger still rejected heat into the supply air stream. It is assumed, though, that during non-business hours when the fuel cell is at minimal load conditions (low co-generated heat output) and the furnace is in Stage Two operation, the co-generated hot water coil is probably absorbing heat. The plus side of this is that the loop fluid was always in motion and kept above freezing temperatures. This is important since the co-generated water loop enters the building three feet above grade. A site-built metal covering protects the above-grade pipes, however the covering is poorly insulated. This winter we experienced colder then normal temperatures over many days. Without the accidental design flaw, we may have suffered some flow problems during the extreme weather.

Circulator pump and a large canister of nitrogen

- *In the center of the picture is the co-generation water loop circulator pump. The flow was measured at 3.8 gpm.*
- *The large black canister is filled with nitrogen used to purge the fuel cell when in shut down or start up.*
- *The nitrogen is supplied to the fuel cell via a plastic hose buried in the utilities trench leading to the fuel cell pad.*

Culligan feed water filter and de-ionizer

- *To the left of the first stage filter is the EPA required back-flow valve. This is required to prevent a contamination of the public water supply by the fuel cell via the feed water connection.*
- *The de-ionizer must maintain a conductivity less than 1.0 microsiemen. This must be checked every 6 months.*

Fuel cell off loaded by boom truck

- *Pad is securely attached to wood foundation and ready for fuel cell attachment.*
- *The boom truck proved to be the best way to maneuver the 3,100-pound fuel cell on to the pad and stub-up connections without damaging them.*

Preparing fuel cell for operation

- *A technician prepares the fuel cell by connecting all wiring and plumbing connections.*
- *The two drawers pulled out on the lower right of the fuel cell are the load-carrying on-board batteries.*
- *All connections were made in less than four hours.*

Finished installation at site No. 2

The propane unit was fully installed and running in less then two days. This unit was not subject to high wind conditions, thus a fence was not required. We had gravel spread around the unit to accommodate the many footprints of onlookers. The drainpipe was installed to facilitate proper drainage around the gravel base. It is a short fifteen feet to the equipment room located just behind the door under the lamp on the building wall. This provides safe and easy access for guided tours to illustrate the co-generation connections, automatic transfer switch, battery charger, and feed water de-ionizer. There is also ample parking for cars and buses. This is truly a good site for public display. Once we feel confident in the fuel cells' operational reliability, we plan on announcing a regular open house schedule.

Fuel Cell Performance for Site No. 1 and 2

H-Power commissioned the fuel cell at site No. 1 (natural gas) on November 08, 2003.

H POWER ENTERPRISES OF CANADA
INSTALLATION, START UP AND COMMISSIONING REPORT

Date From 2002/10/21 To 2002/11/08 Installation No. 20452

Installers Sylvain Leclerc et Oleg Mongor

Commissioner Sylvain Leclerc

Installation checklist

	Date	Initials: H Power	Initials: Client
Installation completed	2002/10/25	L.L.	
Training completed	2002/10/25	L.L.	
System commissioned	2002/11/08	L.L.	
Safety procedures reviewed	2002/10/25	L.L.	
System operated normally for a minimum of 4 hours		L.L.	

Observations (attach report as necessary)

Still need to address internet connection problem

Report is attached YES ___ NO ✓ Report Number – No. of Pages –

Date 2002/11/08 Installer Signature [signature]

Date ______ Installer Signature ______

Client Name Michael J. Rubala (SMECO) Date 11/?/02 Client* Signature [signature]

In signing this document, the client affirms that the site preparation was completed in accordance with H Power's Installation and Operation manual, and that all applicable local codes and standards have been followed.

Acknowledgment

Prod Supp. Mgr. ______ Date ______ Signature ______

Director ______ Date ______ Signature ______

H-Power commissioned the fuel cell at site No. 2 (propane gas) on October 25, 2003.

H POWER ENTERPRISES OF CANADA
INSTALLATION, START UP AND COMMISSIONING REPORT

Date From 2002/10/21 To 2002/10/25 Installation No. 20544

Installers Sylvain Leclerc & Oleg Morozov

Commissioner Sylvain Leclerc

Installation checklist

	Date	Initials H Power	Initials Client
Installation completed	2002/10/21 – 2002/10/25	S.L.	MJR
Training completed	2002/10/24 – 2002/10/25	S.L.	MJR
System commissioned	2002/10/25	S.L.	MJR
Safety procedures reviewed	2002/10/24	S.L.	MJR
System operated normally for a minimum of 4 hours		S.L.	MJR

Observations (attach report as necessary)

HPower Still need to address the internet connection problem.

Customer should install a pressure gauge on the gas line within the unit for easier pressure adjustment. DONE Nov. 06 2002

Report is attached YES____ NO____ Report Number________ No. of Pages_____

Date 2002/10/25 Installer Signature

Date 2002/10/25 Installer Signature

Client Name Michael J. Rubala (SNECO) Date 2002/10/25 Client Signature

In signing this document, the client affirms that the site preparation was completed in accordance with H Power's Installation and Operation Manual, and that all applicable local codes and standards have been followed.

Acknowledgment

Prod Supp. Mgr. ____________ Date ____________ Signature ____________

Director ____________ Date ____________ Signature ____________

In the comment section of both commissioning documents, SMECO stated the remote access monitoring ability of both units was still not functioning. That has never been corrected by H-Power. They tried many times to determine the cause of the on-board computer and modem communication failure but never seemed to resolve the problem. All land-line connections and ISP static access was determined to be functioning properly and not the cause of the remote communication failure. The loss of the remote communication failure prevented any of the parties to monitor fuel cell operation, fuel consumption, shut down occurrence, and to up load performance data remotely. Actual operation of the fuel cell, though, was not affected. Recorded data and status information was collected at the site directly from the on-board computer by H-Power technicians. SMECO felt this was an inconvenience, but it had no bearing on the demonstration project's outcome.

Performance Record

Monthly data:
H-Power technicians uploaded performance data off of both units periodically. The data, when made available by H-Power, will be forwarded to CERL.

Performance problems:
When either fuel cell was operating, the performance was as expected. The units could follow instantaneous loads and maintain support during extensive peaks lasting ten to fifteen minutes easily. When loads exceeded the fuel cells' capacity, the transfer switch operated correctly in moving the load to grid. At the Conservation building site, UPS units that were installed on all personal computers proved to be a wise decision. Whenever the building maintained a demand of 5.0 kW for over thirty minutes, the fuel cell would keep switching back and forth between grid and batteries. Without UPS protection, all productivity in the building would have come to a halt. The same was experienced with site No. 1. When the private residence operated appliances that exceeded the load-carrying capacity of the fuel cell, the unit would switch to grid but some appliances would shut down in response to the loss of power during the transfer. This led to some disgruntled occupants as they thought the dryer was operating, when it had switched off hours before with wet clothes still inside. The remedy was to

restore some loads back to grid permanently. Yes, the fuel cell could operate steady with a 4.0 kW load, but extended loads taxed the batteries. The actual load diversity of both site 1 and site 2 proved to be somewhat unpredictable at times.

Shut downs:
Both units have experienced numerous shutdowns due to onboard alarms or equipment failures. Listed below are the shutdowns experienced per unit and the explained cause to date.

Site No. 1 (Natural gas) commissioned on 11/08/02
11/20/02 **PT-400 ALARM** - *high pressure in the reformer*
12/02/02 Restarted (no reason found for PT-400 ALARM)
12/07/02 **SSR/HV 900 ALARM** - *leak in gas line*
12/10/02 Restarted (replaced faulty main gas valve)
12/10/02 **V-3 ALARM** - *recycled feed water tank over flow*
12/10/02 Restarted (no reason found for V-3 ALARM)
12/10/02 **FLMD ALARM** - *igniter failure for the reformer*
12/18/02 Restarted (fail to restart)
12/18/02 Restarted (no reason found for FLMD ALARM)
12/18/02 **SSR/HC 900 ALARM** - *leak in gas line*
12/18/02 Restarted (no reason found for SSR/HC 900 ALARM)
12/18/02 **SSR/HC 900 ALARM** - *leak in gas line*
01/07/03 Restarted (no reason found for SSR/HC 900 ALARM)
01/07/03 **PCS Contactor ALARM** - *cathode air blower controller failure*
01/08/03 Restarted (no reason found for PCS Contactor ALARM)
01/08/03 **VDCO Low ALARM** - *stack voltage output response low*
01/08/03 Shut down unit for stack replacement by H-Power technician
Still out of operation as of 03/03/03

Site No. 2 (Propane gas) commissioned on 10/25/02
10/26/02 **SSR/H2 ALARM** - *hydrogen leak*
11/05/02 Restarted (no reason found for SSR/H2 ALARM)
11/05/02 **SSR/H2 ALARM** - *hydrogen leak*
11/05/02 Restarted (no reason found for SSR/H2 ALARM)
11/05/02 **SSR/H2 ALARM** - *hydrogen leak*
11/05/02 Restarted (no reason found for SSR/H2 ALARM)
11/05/02 **SSR/H2 ALARM** - *hydrogen leak*
11/05/02 Restarted (no reason found for SSR/H2 ALARM)

11/06/02 **SSR/HC 900 ALARM** – *propane gas leak*
11/06/02 Restarted (tightened some fittings)
11/06/02 **SSR/HC 900 ALARM** – *propane gas leak*
11/06/02 Restarted (tightened more fittings)
11/06/02 **VDCO Low ALARM** – *air starvation to stack*
11/06/02 Restarted (no problem found)
11/06/02 **SSR/H2 ALARM -** *hydrogen leak*
11/06/02 Restarted (no reason found for SSR/H2 ALARM)
11/06/02 **SSR/H2 ALARM -** *hydrogen leak*
11/06/02 Restarted (replaced faulty hydrogen gas alarm)
11/07/02 ***PT-400 High ALARM*** – *high pressure in reformer*
11/07/02 Restarted (result of PT-400 ALARM shut down)
11/08/02 **SSR/HC 900 ALARM** – *propane gas leak*
11/08/02 Restarted (no leak found)
11/18/02 **FLMD ALARM** – *fuel or air deficiency to burner*
11/18/02 Restarted (unknown problem)
11/20/02 **FLMD ALARM** – *fuel or air deficiency to burner*
11/20/02 Restarted (problem not found)
11/20/02 **FLMD ALARM** – *fuel or air deficiency to burner*
11/20/02 Restarted (problem not found)
11/20/02 **FLMD ALARM** – *fuel or air deficiency to burner*
11/20/02 Restarted (problem not found--assumed programming error)
11/20/02 **SSR/HC 900 ALARM** – *propane gas leak*
11/20/02 Restarted (replaced faulty gas detector)
12/03/02 **PT-400 High ALARM** – *high pressure in reformer*
12/02/02 Restarted (no problem found)
12/05/02 **FLMD ALARM** – *fuel or air deficiency to burner*
12/05/02 Restarted (no problem found)
12/10/02 **FLMD ALARM** – *fuel or air deficiency to burner*
12/10/02 STOP (shut down for repair due to FLMD ALARM)
01/07/03 Restarted (replaced air booster fan to burner)
01/23/03 **M-1** ***ALARM*** – *enthalpy wheel motor failure*
02/03/03 Restarted (test to determine if M-1 motor has failed)
02/03/03 **M-1** ***ALARM*** – *enthalpy wheel motor failure*
02/03/03 STOP (shut down for repair due to M-1 ALARM)
02/12/03 Restarted (replaced M-1 motor)
Still in operation as of 03/03/03

Both units have experienced numerous nuisance alarms followed by a shutdown. Other than the site No. 1 fuel cell stack failure resulting in a permanent shut down until replaced, the main fuel cell process performed well. Components that needed to be replaced were off-the-shelf products not designed exclusively for the fuel cells' operation. So far, there have not been any problems in reformer production of hydrogen. The removal of sulfur from the feedstock and damaging levels of CO from the reformer process has performed as designed. Load following capabilities utilizing onboard batteries and H2 stack feed logic seemed to work as designed. Co-generated heat output was effectively collected and made available for use as designed. The only real complaint from the occupants of both sites was that of noise. The noise complaint was caused by the onboard cooling fan used to dissipate excess heat to the environment from the stack-cooling loop (co-generated heat). When the fan was off, the unit was very quiet. If all co-generated heat were used at all times, there would be no excess waste heat--thus no fan operation. For the most part, loose fittings, minor ancillary component failures, and programmed operational logic with tolerances that were too tight for field operations seemed to be the biggest problems so far.